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Simulation experiment research of the impact of CO_2 leakage from geological storage on soil microbes

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Abstract

CCS is considered to be the most effective way to control the CO_2 emissions. But there is a risk of leakage with CCS projects during the process of actual operation. So, it is important to research the leakage of CCS. In this article, the range of CO_2 concentration which affects the inhibition and promotion of microorganism growth can be determined by analyzing the response of soil microbes in different CO_2 concentrations. The soil microbial indicators of sorghum have a similar trend when the concentration of CO_2 between normal atmosphere and 80000μmol/mol. It shows a decreasing trend after the first increase. And the indicators reach the maximum at 20000μmol/mol and the minimum at 80000μmol/mol respectively. The leakage of the CCS project can be evaluated by analyzing the response of soil microbes in the future.

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Keywords: CCS;Risk; Soil microbes; Effect.

1. Introduction

At present, Carbon Capture and Storage (CCS) is considered to be the most promising and effective way to control the CO2 emissions [1]. It was listed as one of the major measures for future global carbon reduction at the Durban Conference. Although Carbon Capture and Storage has a wide horizon of development, it is still in the stage of exploration in China [2]. There is a risk of leakage with CCS projects during the process of actual operation. And the leakage has an adverse effects on the surrounding ecological environment. It may lead to unfavourable influence

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on ecological environment although it can reduce the emissions of CO_2 [3, 4, 5] .Therefore, in order to find potential problems timely, it is extremely urgent to do the research on the problem of leakage (Ma J. et al, 2013). Several studies suggest that soil microbes is the most sensitive and active factor to the elevated CO_2 [6]. Therefore, to study the change of soil microbes under the condition of high concentration of CO_2 is an important way to evaluate the condition of leakage and the risk of CCS projects quantitatively.

In order to understand what impacts such leakage may be brought about to soil microbes, the carbon dioxide artificial climate chamber with the pot culture was used to research the effects of different concentrations of CO2 (normal atmospheric, 10000μmol/mol, 20000μmol/mol, 40000μmol/mol, 80000μmol/mol) on soil microorganism quantity, respiration, microbial biomass C and N of sorghum in this paper. By analysing the response of soil microbes in different CO2 concentrations. The ranges of CO2 concentration was determined which affects the inhibition and promotion of microorganism growth. Microbial indicators were selected for establishing risk assessment of CO2 leakage.

2. Materials and methods

2.1 Soil samples

Soil samples were come from the pots in which sorghum was cultivated 21days in CO_2 artificial climate chamber on normal atmospheric, 10000μmol/mol, 20000μmol/mol, 40000μmol/mol and 80000μmol/mol of CO_2 concentrations. The original soil were sampled from the farmland in Jingbian County, China, CO_2 injection test area of Shaanxi Yanchang Petroleum Co. Ltd. [7]. The soil type belongs to regosols on Loess Plateau, and was named as Huangmiantu soil. its texture is sandy loam.

Before planting the crop, the soil was mixed well, and adjust the soil to a certain humidity to ensure normal crop seeds germinate. In the process of planting, the pots were watered once every 2-3 days to ensure water demands of sorghum.

2.2 Indicators and measurement methods

Soil microbial quantity was determined by dilution plate method. Bacteria, actinomycetesis and fungi were cultured by NA, NG, and bengal rose separately. The chloroform fumigation-instrument analysis was used to measure the soil microbial biomass C. Alkaline potassium persulfate-ultraviolet spectrophotometer is used to measure the soil microbial biomass N. Soil microbial respiration rate was determined by titration with alkali absorption.

3. Results

3.1 Soil microbial quantity

The influence of elevated CO_2 on the soil microbial (bacteria, fungi and actinomycetes) quantity of planting sorghum had a same trend. The soil microbial quantity of planting sorghum increased at first and then descended with the increasing of the CO_2 concentration (Fig.1). When the concentration of CO_2 between normal atmosphere and 20000μmol/mol, the amounts of soil microorganism of planting sorghum increased gradually with the increasing of CO_2 concentration. And the amounts of soil microorganism reach the maximum at 20000μmol/mol. The maximum of bacteria, fungi and actinomycetes were 5.448×106CFU/g, 11.463×104CFU/g, 8.55×106CFU/g respectively. Compared with the normal atmosphere, the quantity of bacteria, fungi and actinomycetes of planting sorghum were increased respectively by 112.98%, 91.76% and 67.86%. However, when the CO_2 concentration was greater than 20000μmol/mol, with the increasing of CO_2 concentration, the number of soil microorganisms decreased gradually, the growth and reproduction of all kinds of microorganism in the soil were inhibited. The amounts of soil microorganism reached minimum at 80000μmol/mol CO_2 concentration. The minimum were

0.932×106CFU/g, 4.606×104CFU/g, 3.982×106CFU/g. Compared with the normal atmosphere, the quantity of bacteria, fungi and actinomycetes of sorghum were reduced respectively by 63.57%, 45.84% and 35.05%.

3.2 Soil microbial biomass

The soil microbial biomass C and soil microbial biomass N of planting sorghum had a same significant change when the concentration of CO_2 was from normal atmosphere to 80000μmol/mol. It showed a decreasing trend after the first increase (Fig.2). Along with the increasing of CO_2 concentration, soil microbial biomass increased gradually and reached the maximum at 20000μmol/mol. The maximum of soil microbial biomass C of planting sorghum was 211.50 mg/kg, the maximum of soil microbial biomass N was 21.825 mg/kg. When the CO_2 concentration was greater than 20000μmol/mol, the soil microbial biomass decreased gradually and reached the maximum at 80000μmol/mol. The minimum of soil microbial biomass C of sorghum was 69.468mg/kg, the minimum of soil microbial biomass N was 4.067 mg/kg.

3.3 Soil microbial respiration

Soil respiration includes soil microbial respiration, plant root respiration and soil animal's respiration. Among them, soil microbial respiration accounted for about 76% of the total soil respiration, and was the dominant of soil respiration [8].

The trend of the intensity of soil microbial respiration of planting sorghum increased in initial stage and then declined with the increasing of the CO_2 concentration (Fig.3). When the concentration of CO_2 was from normal atmosphere to 20000μmol/mol, the intensity of soil microbial respiration of planting sorghum was enhanced gradually with the increasing of CO_2 concentration, and it reached the maximum at 20000μmol/mol. When the CO_2 concentration was greater than 20000μmol/mol, the soil microbial respiration of planting sorghum was reduced gradually, and reached the minimum at 80000μmol/mol. Compared with the normal atmosphere, the soil microbial respiration of planting sorghum were increased by 16.36% and 30.91% respectively when the CO_2 concentration were at 10000 μmol/mol and 20000 μmol/mol, the soil microbial respiration of planting sorghum were decreased 9.09% and 21.82% when the CO_2 concentration were at 40000 μmol/mol and 80000 μmol/mol.

4. Discussion

4.1 The effect of elevated CO_2 on soil microbial quantity

According to the results of experiments, when the CO_2 concentration in the range of normal atmospheric to 20000μmol/mol, there was an obvious improving role for soil microbial growth and reproduction of planting

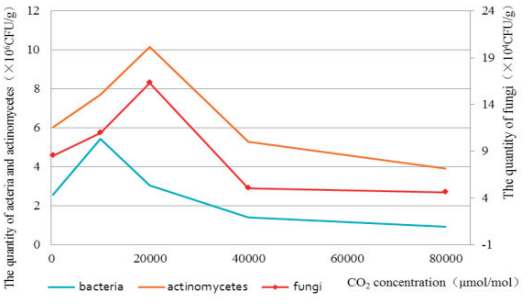

Fig. 1. The quantity of soil microbial of planting sorghum under different CO_2 concentration

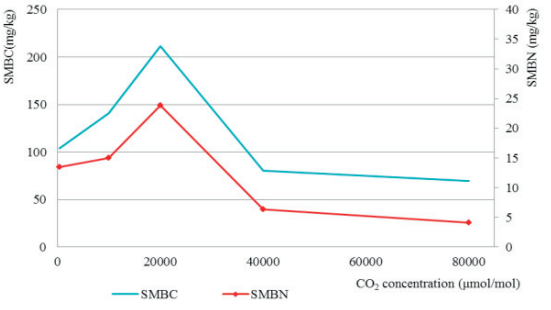

Fig. 2 The soil microbial biomass C and N of planting sorghum under different CO_2 concentration

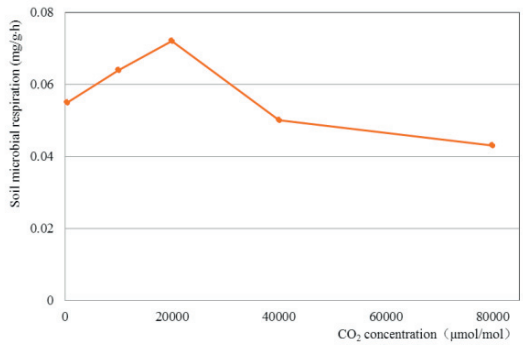

Fig.3 The soil microbial respiration of planting sorghum under different CO_2 concentration

sorghum with elevated CO2, especially at 20000μmol/mol. When the CO2 concentration were greater than 20000μmol/mol, elevated CO2 inhibited the growth and breeding of soil microbial of planting sorghum, and the inhibition was the most obvious when the CO2 concentration was at 80000μmol/mol.

Some study showed that the CO_2 concentration in the atmosphere is generally 10 to 50 times of that in the soil. Atmospheric CO_2 rarely have a direct impact on soil microbial, the atmospheric CO_2 could directly affect photosynthesis and respiration, carbon carried to roots, and finally to soil microbial. However, when the CO_2 concentration in the atmospheric is much higher than the soil, atmospheric CO_2 may have a directly impact on soil microbial.

The results of plant indicators under the elevated CO_2 showed that there is the same trend between morphological indexes, physiological indexes and biomass of the plant and soil microbial quantity. When the concentration of CO_2 were increased from normal atmosphere to 20000μmol/mol, elevated CO_2 promoted the growth of plant, the plant photosynthesis become stronger, it provided a wealth of organic substrates for soil microorganisms, so as to promote the growth and reproduction of soil microbe. When the CO_2 concentration were greater than 20000μmol/mol, the indicators of plant were restrained, the overall metabolism function of plant were dropped, and the nutrients in plant transformation were reduced, thereby the growth of the soil microorganisms was inhibited. Moreover, when the CO_2 concentration in the atmosphere was much higher than that in the soil, a portion of the CO_2 may entered the soil, and had a direct influence on microorganisms. It may led to the deaths of a lot of soil microbial, and the soil microbial quantity was decreased.

4.2 The effect of elevated CO_2 on soil microbial biomass

The soil microbial biomass of planting sorghum showed a decreasing trend after the first increase. When the CO_2 concentration were from normal atmospheric to 20000μmol/mol, elevated CO_2 had a promoting effect on soil microbial biomass. When the CO_2 concentration were greater than 20000μmol/mol, elevated atmospheric CO_2 had a inhibiting effect on soil microbial biomass, the inhibition was the most obvious when the CO_2 concentration at 80000 μ mol/mol.

There are two ways that elevated CO_2 influence the soil microbial biomass: the indirect way and the direct way. When the CO_2 concentration is lower than 20000μmol/mol, the atmospheric CO_2 concentration is significantly lower than the soil. Therefore, at this stage, elevated CO_2 is mainly indirect effects on soil microbial biomass by plants. However, when the CO_2 concentration from 20000 to 80000μmol/mol, plant physiology and morphology index is suppressed, the overall metabolic function decline, and the nutrients in soil transferred by photosynthesis is decreased. Soil microbial activity is reduced by the lack of adequate nutrients, and even death. It can affect the soil

microbial biomass at some level. In addition, when the CO_2 concentration increases, some protozoa, collembola and nematode in soil which are fed by soil microbial increase relevantly. Soil microbial quantity and soil microbial biomass decrease also.

4.3 The effect of elevated CO_2 on soil microbial respiration.

The trend of the intensity of soil microbial respiration of planting sorghum increased in initial stage and then declined. With the increasing of the CO_2 concentration, soil microbial respiration increased gradually, and reached the maximum at 20000μmol/mol. After that, soil microbial respiration weakened gradually, and reached the minimum at 80000μmol/mol. This tendency was consistent with the result of Zou's research [9].

Soil microorganisms have an intimate contact with the plant and the two factors affects each other. When the CO_2 concentration is raised, the plant photosynthesis becomes stronger, and the nutrients transferred by photosynthesis increase gradually. Moreover, elevated CO_2 promotes the growth of plant roots, it is easier to transport the nutrients to the soil. Activity of soil microbes is strengthened because it have enough organic substrates. It makes the soil microbial respiration intensity increased. When the CO_2 concentration is high enough, it constrains the plant's growth and reduces the photosynthesis, and the nutrients in soil transferred by photosynthesis is decreased. It leads to reduce the soil microbial activity and respiration rate.

5. Conclusion

Over all, the soil microbial indicators of planting sorghum have a similar trend when the concentration of CO_2 between normal atmosphere and 80000μmol/mol. It shows a decreasing trend after the first increase. The indicators reach the maximum and minimum at 20000μmol/mol and 80000μmol/mol respectively.

6. Acknowledgements

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